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Univalence of certain integral operators

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Abstract

Let \mathcal{A}_n be the class of functions $f(z)$ which are analytic and n -fold symmetric in the open unit disk \mathbb{U} . The integral operator $G_\alpha(z)$ for $f(z) \in \mathcal{A}_n$ is considered. The object of the present paper is to derive univalence conditions of the integral operator $G_\alpha(z)$ for $f(z) \in \mathcal{A}_n$.

1 Introduction

Let \mathcal{A}_n denote the class of functions $f(z)$ of the form

$$f(z) = z + \sum_{k=1}^{\infty} a_{nk+1} z^{nk+1} \quad (n \in \mathbb{N} = \{1, 2, 3, \dots\})$$

which are analytic and n -fold symmetric in the open unit disk $\mathbb{U} = \{z \in \mathbb{C} : |z| < 1\}$. We denote by \mathcal{S}_n the subclass of \mathcal{A}_n consisting of functions $f(z)$ which are univalent in \mathbb{U} . Many authors studied the problem of integral operators for functions $f(z)$ in the class \mathcal{S}_1 . In this sense, the following useful result is due to Pfaltzgraff [3].

Theorem 1.1. *If $f(z)$ is univalent in \mathbb{U} and α is complex number with $|\alpha| \leq \frac{1}{4}$, then the integral operator $G_\alpha(z)$ given by*

$$G_\alpha(z) = \int_0^z (f'(t))^\alpha dt \tag{1}$$

is also univalent in \mathbb{U} .

Further, Pascu and Pescar [2] gave

Theorem 1.2. *If $f(z) \in \mathcal{S}_1$ and α is a complex number with $|\alpha| \leq \frac{1}{4n}$, then the integral operator $G_{\alpha,n}(z)$ given by*

$$G_{\alpha,n}(z) = \int_0^z (f'(t))^\alpha dt$$

is also in the class \mathcal{S}_1 for all positive integer n .

2 Properties of integral operators

To discuss our problems for integral operators, we need to recall here the following lemma due to Becker [1].

Lemma 2.1. *If $f(z) \in \mathcal{A}_1$ satisfies*

$$(1 - |z|^2) \left| \frac{zf''(z)}{f'(z)} \right| \leq 1 \quad (z \in \mathbb{U}), \quad (2)$$

then $f(z) \in \mathcal{S}_1$.

Applying the above lemma, we derive

Theorem 2.1. *If $f(z) \in \mathcal{A}_1$ satisfies the inequality (2) for all $z \in \mathbb{U}$, then the integral operator $G_\alpha(z)$ defined by (1) belongs to the class \mathcal{S}_1 for all α ($|\alpha| \leq 1$).*

Proof. Note that $G_\alpha(z) \in \mathcal{A}_1$ for $f(z) \in \mathcal{A}_1$ and that

$$\frac{zf''(z)}{f'(z)} = \frac{1}{\alpha} \frac{zG_\alpha''(z)}{G_\alpha'(z)}.$$

It follows that

$$(1 - |z|^2) \left| \frac{zG_\alpha''(z)}{G_\alpha'(z)} \right| = |\alpha|(1 - |z|^2) \left| \frac{zf''(z)}{f'(z)} \right| \leq |\alpha| \leq 1$$

for $z \in \mathbb{U}$. Thus, using Lemma 2.1, we have $G_\alpha(z) \in \mathcal{S}_1$.

Next, we prove

Corollary 2.1. *If $f(z) \in \mathcal{A}_1$ satisfies*

$$\left| \frac{f''(z)}{f'(z)} \right| \leq 1 \quad (z \in \mathbb{U}),$$

then the integral operator $G_\alpha(z)$ defined by (1) is in the class \mathcal{S}_1 with $|\alpha| \leq \frac{3\sqrt{3}}{2}$.

Proof. In view of the proof of Theorem 2.1, we see that

$$(1 - |z|^2) \left| \frac{zG_\alpha''(z)}{G_\alpha'(z)} \right| \leq |\alpha|(1 - |z|^2)|z| \leq 1,$$

because $|\alpha| \leq \frac{3\sqrt{3}}{2}$ and

$$\max_{|z| \leq 1} (1 - |z|^2)|z| = \frac{2}{3\sqrt{3}}.$$

Thus, by Lemma 2.1, we prove that $G_\alpha(z) \in \mathcal{S}_1$.

Finally, we show

Theorem 2.2. If $f(z) \in \mathcal{A}_n$ satisfies

$$\left| \frac{f''(z)}{f'(z)} \right| \leq |z|^{n-1} \quad (z \in \mathbb{U}),$$

then the integral operator $G_\alpha(z)$ defined by (1) belongs to the class \mathcal{S}_n with

$$|\alpha| \leq \frac{(n+2)^{\frac{n+2}{2}}}{2n^{\frac{n}{2}}}.$$

Proof. Since

$$\frac{zf''(z)}{f'(z)} = \frac{1}{\alpha} \frac{zG''_\alpha(z)}{G'_\alpha(z)} = n(n+1)a_{n+1}z^n + \dots,$$

we have that

$$\begin{aligned} (1-|z|^2) \left| \frac{zG''_\alpha(z)}{G'_\alpha(z)} \right| &= |\alpha|(1-|z|^2) \left| \frac{zf''(z)}{f'(z)} \right| \\ &\leq |\alpha|(1-|z|^2)|z|^n \quad (z \in \mathbb{U}). \end{aligned}$$

Note that

$$|\alpha| \leq \frac{(n+2)^{\frac{n+2}{2}}}{2n^{\frac{n}{2}}}$$

and

$$(1-|z|^2)|z|^n \leq \frac{2n^{\frac{n}{2}}}{(n+2)^{\frac{n+2}{2}}} \quad (z \in \mathbb{U}).$$

This gives us that

$$(1-|z|^2) \left| \frac{zG''_\alpha(z)}{G'_\alpha(z)} \right| \leq 1 \quad (z \in \mathbb{U}).$$

Further, it is easy to see that $G_\alpha(z) \in \mathcal{A}_n$. This completes the proof of the theorem.

Remark. For $n = 1$, Theorem 2.2 becomes Theorem 2.1.

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